

## COMPOSITE STRUCTURE AND METHOD FOR CONSTRUCTING SAME

## TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the field of composites construction, and more particularly to a composite structure and method for constructing same.

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BACKGROUND OF THE INVENTION

Composite structures are desirable in many industries for many applications. For example, aircraft, space, and land/sea vehicles employ a variety of curved and multiple-contoured surface structures in their fabrication. Composite materials are commonly used for these structures because, among other desirable attributes, composite materials have high strength-to-weight ratios. Even so, composite structures formed from composite materials oftentimes need to be stiffened. Therefore, manufacturers of composite structures are continually searching for better and more economical ways of stiffening composite structures.

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SUMMARY OF THE INVENTION

According to one embodiment of the invention, a method of constructing a composite structure includes positioning a plurality of forming elements on a skin panel formed from a composite material in a predetermined configuration, disposing a stiffening panel formed from an uncured composite material outwardly from the forming elements to create a plurality of contact regions between the skin panel and the stiffening panel, and curing the skin panel and the stiffening panel to bond the skin panel and the stiffening panel together at the contact regions.

Embodiments of the invention provide a number of technical advantages. Embodiments of the invention may include all, some, or none of these advantages. In one embodiment, less weight of stiffened composite structures is achieved. This weight reduction is particularly advantageous in aircraft applications. No mechanical fasteners or adhesives are needed to attach the stiffening panel to the composite panel, which saves considerable time and money in constructing stiffened composite structures. However, Z-pins may be used to complement the bonding of the stiffening panel to the composite panel to create crack propagation resistance. An additional technical advantage is that the quality of stiffened composite structures is improved by substantially reducing or eliminating folds, kinks, bumps, or other imperfections when laying-up composite stiffening panels on composite panels.

Other technical advantages are readily apparent to one skilled in the art from the following figures, descriptions, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention, and for further features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

5           FIGURE 1 is a perspective view of an aircraft having a panel formed from a composite structure constructed according to one embodiment of the present invention;

FIGURE 2 is a perspective view of the composite structure of FIGURE 1;

10           FIGURES 3A through 3C are perspective elevational views illustrating one method of constructing a composite structure according to one embodiment of the present invention; and

FIGURE 3D is a perspective elevational view of a composite structure in a waffle configuration constructed according to one embodiment of the present invention.

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DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of the present invention and their advantages are best understood by referring now to FIGURES 1 through 3D of the drawings, in which like numerals refer to like parts.

FIGURE 1 is a perspective view of an aircraft 100 having a panel 102 formed from a composite structure 200 (FIGURE 2) constructed according to one embodiment of the present invention. Aircraft 100 may be any suitable aircraft and panel 102 may be any suitable structural panel on aircraft 100, such as a wing panel, a tail panel, or a fuselage panel. Although aircraft 100 is illustrated in FIGURE 1, panel 102 may be employed in any suitable aircraft, space, land/sea vehicle, or other machines, devices, or structures formed by composite materials. Oftentimes, structures formed from composite materials need to be stiffened. The following detailed description uses an aircraft application to illustrate one or more embodiments of composite structure 200 manufactured according to the teachings of the present invention. One embodiment of composite structure 200 is illustrated below in conjunction with FIGURE 2.

FIGURE 2 is a perspective view of one embodiment of composite structure 200. Composite structure 200 includes a skin panel 202, a plurality of forming elements 204, and a stiffening panel 206. Composite structure 200 may also include a plurality of fasteners 208 coupling skin panel 202 and stiffening panel 206.

Skin panel 202 is formed from any suitable composite material, such as graphite epoxy or graphite bismaleimide ("bmi"). Skin panel 202 may have any suitable number of layers and the fibers that are included in skin panel 202 may be unidirectional, bi-directional, or have any suitable orientation. In the illustrated embodiment, skin panel 202 forms a portion of an outer skin of aircraft 100. For example, skin panel 202 may coincide with a portion of the outer skin of a wing, a tail section, or a fuselage section. Accordingly, skin panel 202 may have any suitable shape, dimensions, and thickness. In addition, skin panel 202 may be substantially flat or may have one or more contours to conform to the shape of a particular portion of aircraft 100.

Forming elements 204 are utilized to impart a predetermined configuration to stiffening panel 206, as described more fully below in conjunction with FIGURES 3A through 3D. The properties and weight of forming elements 204 are selected according to end-use requirements. For example, in some embodiments, forming elements 204 are "flyaway" tooling mandrels formed from a lightweight material suitable for permanent incorporation into composite structure 200, such as low-density, closed cell epoxy or bmi foam, or other suitable polymeric foams, such as carbon or graphitic foam, having suitable compression strength. Other suitable materials may be such materials as balsa wood, honeycomb structures, or open cell foams. In other embodiments, forming elements 204 are such that after composite structure 200 is formed, forming elements 204 are removable via any suitable meltout or washout technique. In still other embodiments, forming elements 204 may be composed of a thin shell of material that is filled with a meltout or washout type of material where the thin shell is suitable for permanent incorporation into composite structure 200. For example, a thin shell could be formed from a thermoformed plastic, such as ABS, and filled with a removable material, such as a water soluble eutectic salt.

As discussed more fully below in conjunction with FIGURES 3A through 3D, forming elements 204 may be any suitable size or shape and may form any suitable configuration when positioned on skin panel 202. In the illustrated embodiment, forming elements 204 form a corrugated configuration on skin panel 202; however, other configurations, such as waffle configurations may be formed.

Stiffening panel 206 is formed from any suitable composite material, such as graphite epoxy or graphite bmi. To facilitate bonding between stiffening panel 206 and skin panel 202, stiffening panel 206 typically includes a resin that is the same as the resin in skin panel 202; however, other suitable resins may be used. In one embodiment, stiffening panel 206 is formed from a composite material having a plurality of discontinuous fibers so that stiffening panel 206 may be flexible enough to form over forming elements 204, as discussed more fully below in conjunction with FIGURES 3A through 3D. In a particular embodiment, stiffening panel 206 is formed from a composite material having chopped fibers that is sprayed on using

well-known spraying techniques onto forming elements 204 and skin panel 202, as discussed more fully below. In other embodiments, the fibers used in the composite material for stiffening panels 206 may be unidirectional, bi-directional, or have any suitable orientation.

5           Stiffening panel 206 may be formed from any suitable number of layers and may have any suitable size or shape before being placed onto forming elements 204 and skin panel 202. In one embodiment, stiffening panel 206 has the same width as skin panel 202 but is longer than skin panel 202 such that when stiffening panel 206 forms over forming elements 204 it ends up being approximately the same length as skin panel 202. This reduces or eliminates any trimming or finishing operations after composite structure 200 is formed.

10           Fasteners 208, in one embodiment, are Z pins; however, other suitable fasteners may be used. One purpose of fasteners 208 is for damage resistance. In other words, if a crack starts to develop in composite structure 200 fasteners 208 inhibit crack propagation. As illustrated in FIGURE 2, fasteners 208 couple skin panel 202 and stiffening panel 206 at one or more contact regions 210. Fasteners 208 may be inserted by any suitable process, such as pushing or driving while being vibrated with ultrasonic energy.

15           Now that various elements of composite structure 200 have been described, one method of constructing composite structure 200 is described below in conjunction with FIGURES 3A through 3C.

20           FIGURES 3A through 3C are perspective elevational views illustrating one method of constructing composite structure 200. The method starts with skin panel 202, as illustrated in FIGURE 3A. Skin panel 202, which as described above is formed from any suitable composite material having any suitable dimensions, is provided in either a cured or uncured state. Skin panel 202 is placed on any appropriate flat or suitably contoured working table or tool (not explicitly shown).

25           The next step in the method is outlined in FIGURE 3B. Forming elements 204 are positioned on skin panel 202 in a predetermined configuration. In the illustrated embodiment, the predetermined configuration is a corrugated configuration; however, other suitable configurations are feasible, such as a waffle  
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configuration (FIGURE 3D). Although not illustrated, forming elements 204 may have tapered ends. Forming elements 204 may be located on skin panel 202 by any suitable means, such as a laser positioning locator, a hard positioning template, or by measuring from one or more reference points. After forming elements 204 are positioned in the predetermined configuration, stiffening panel 206 is applied on the top of skin panel 202 and forming elements 204, as illustrated in FIGURE 3C.

FIGURE 3C shows stiffening panel 206 draped over forming elements 204, thereby forming contact regions 210 between stiffening panel 206 and skin panel 202. For stiffening panel 206 to have the ability to conform to the predetermined configuration created by forming elements 204, stiffening panel 206 is typically formed from an uncured composite material. In addition, the fibers that are part of the composite material that stiffening panel 206 is formed from are, in one embodiment, discontinuous fibers. The fibers may, in other embodiments, be continuous; however, if continuous then the direction of the fibers needs to be in approximately the same direction as the direction of stretching of stiffening panel 206. An important consideration when applying stiffening panel 206 is that substantially no air gaps exist between the bottom surface of stiffening panel 206 and the top surface of skin panel 202. This insures that adequate bonding takes place between stiffening panel 206 and skin panel 202 at contact regions 210 when the composite material is cured, as described more fully below. As an option, although not required, adhesive may be applied at contact regions 210 if so desired. However, an important technical advantage of one embodiment of the present invention is that stiffening panel 206 and skin panel 202 may be coupled to one another without the use of adhesives and/or mechanical fasteners. This saves considerable time and money in constructing composite structure 200. In a particular embodiment illustrated by arrow 300, stiffening panel 206 is sprayed on the surface of skin panel 202 and forming elements 204 using any suitable well-known composite spraying techniques. This embodiment may be particularly suitable for stiffening panels that are formed in a waffle configuration, such as stiffening panel 206 illustrated in FIGURE 3D.

The next step in the method is to cure skin panel 202 and stiffening panel 206, whereby skin panel 202 and stiffening panel 206 are bonded together at contact



regions 210. Any suitable curing techniques well-known in the art of composites forming may be utilized. For example, composite structure 200 may be enveloped in a vacuum bag, a vacuum pulled, and then placed in an autoclave with suitable temperature and pressure to cure the composite materials. The matrix used in the composite materials may be thermosetting or thermoplastic. If thermoplastic, then higher curing temperatures would be involved. Composite structure 200 is heated and pressurized for a predetermined time so that the composite material may sufficiently cure. Any trimming or finishing of composite structure 200 may then take place, which ends one method of forming composite structure 200.

Other methods of curing composite structure 200 may be utilized. For example, two mechanical presses may be used to bond stiffening panel 206 to skin panel 202. In this embodiment, composite structure 200 would be heated to a sufficient temperature before the presses are pressed together for a sufficient time to cure the composite materials. In another embodiment, a resin transfer molding ("RTM") process may be used, wherein dried fabric is used for stiffening panel 206 and skin panel 202 and injected with any suitable resin. Other suitable curing processes may be utilized.

Although not illustrated in FIGURES 3A through 3C, another step in the method may be to couple skin panel 202 and stiffening panel 206 with fasteners 208 proximate contact regions 210. In this embodiment, skin panel 202 would need to be in an uncured or partially cured state so that skin panel 202 is deformable enough to facilitate the inserting of fasteners 208. In one embodiment, fasteners 208 may be Z-pins, which act to resist any damage during usage of composite structure 200.

Another option in the method outlined in FIGURES 3A through 3C is to remove forming elements 204 after final curing of skin panel 202 and stiffening panel 206. As outlined above, forming elements 204 would then have to be formed from a material or materials that facilitate their removal. For example, forming elements 204 each may be a rubber bladder filled with sand or eutectic salt with a vacuum pulled on it. Other suitable meltout or washout type of materials may also be used.

Although embodiments of the invention and their advantages are described in detail, a person skilled in the art could make various alterations, additions, and

omissions without departing from the spirit and scope of the present invention as defined by the appended claims.

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